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ASSESSMENT OF THE MIGRATIONAL HABITS, GROWTH, AND ABUNDANCE OF THE ARCTIC GRAYLING STOCKS OF THE GULKANA RIVER DURING 1989[1]

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ABSTRACT

Arctic grayling *Thymallus arcticus* were sampled in selected locations in the Gulkana River drainage during 1989. Fish were captured by electrofishing and hook and line gear in the mainstem and by weir trapping and electrofishing in one of its tributaries used for spawning by Arctic grayling. A total of 9,298 adult Arctic grayling over 199 millimeters fork length were caught in the Gulkana River drainage, of which 1,876 were previously marked. In addition, 794 juvenile Arctic grayling less than 200 millimeters fork length were caught in the drainage. Recaptures of marked fish show that Arctic grayling in the Gulkana River undergo intensive migrations. Arctic grayling sampled in the Gulkana River drainage during the study ranged from age 0 to age 8 and were predominantly age 2, 3, and 4 fish. Data are also presented on length distributions, capture probabilities, age composition, and mean length-at-age. Population estimates for the drainage as a whole and the areas heavily fished by sport anglers are presented and discussed along with future study directions.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, Gulkana River, migration, mark-recapture, age, growth, length.

INTRODUCTION

The Gulkana River is located midway between Anchorage and Fairbanks along the Richardson Highway and is tributary to the Copper River. The river, recently classified as wild and scenic by the U.S. Congress, provides substantial recreational value to the community of Glennallen as well as to southcentral and interior Alaska (Jones and Stokes 1987). The river supports one of the largest recreational fisheries for Arctic grayling *Thymallus arcticus* in the Upper Copper River drainage (Figure 1).

Significant declines in populations of Arctic grayling have occurred in recent years in several of the major fisheries of interior Alaska (Holmes et al. 1986). These declines have placed increased demand on the stocks of Arctic grayling in the Gulkana River to meet the recreational needs of anglers targeting these fish. This has been reflected in increased numbers of float anglers in the upper reaches of the Gulkana River as well as increased numbers of boat and shore anglers in the remaining portions of the river. Angler effort by people floating the Gulkana River increased by 68% from 1980 to 1983, and the catch of Arctic grayling by float anglers increased 272% during the same period (Williams and Potterville 1984, 1985).

Annual sampling of Arctic grayling harvested in the sport fishery on the Gulkana River from 1978 through 1982 indicates that the sport harvest is made up primarily of age 3 and 4 fish (Williams and Potterville 1983). The mean fork length of the sport catch has remained relatively stable at approximately 280 mm from 1968 through 1982, but there was an observed decrease of approximately 40 mm in the maximum size of Arctic grayling in the sport catch during that time (Williams and Potterville 1983).

Life history strategies of Arctic grayling vary from stocks which utilize a single river to stocks having complex migration patterns in large river drainages. In general, Arctic grayling begin an upstream spawning migration to mainstem river or tributary spawning areas in the spring. The migration is initiated as water temperatures reach 0.5 to 1.0°C (Behlke et al. 1988, Tack 1980) and coincides with rising water flows and temperatures (Tack 1974). Spawning begins as temperatures reach 3.9°C, occurs at or near flood stage (Tack 1980), and lasts from 1 to 3 weeks (Tack 1972, McPhee and Watts 1976, Tack and Fisher 1977). The fry hatch in 2 to 4 weeks (Bishop 1971) and undergo a period of rapid summer growth in their natal areas to a length of approximately 100 mm (Morrow 1980). As water temperatures and flows decrease in the fall, the juvenile grayling migrate to deep pools, lakes, or larger river systems to overwinter (Tack 1980).

Most adult grayling leave the spawning areas shortly after spawning and migrate to summer feeding areas (McPhee and Watts 1976, Williams and Morgan 1974, and Williams 1975). Intrastream movements decrease after the grayling reach their summer feeding areas by early July, although there may be migrations into cooler tributary waters during periods of low flows and high water temperatures in the main river (Tack 1980). Arctic grayling are generally distributed in clearwater rivers with the largest adults found the furthermost upstream in the prime feeding areas while the sub-adults and juveniles are found in the lower stream sections (Tack 1980). Arctic grayling migrate

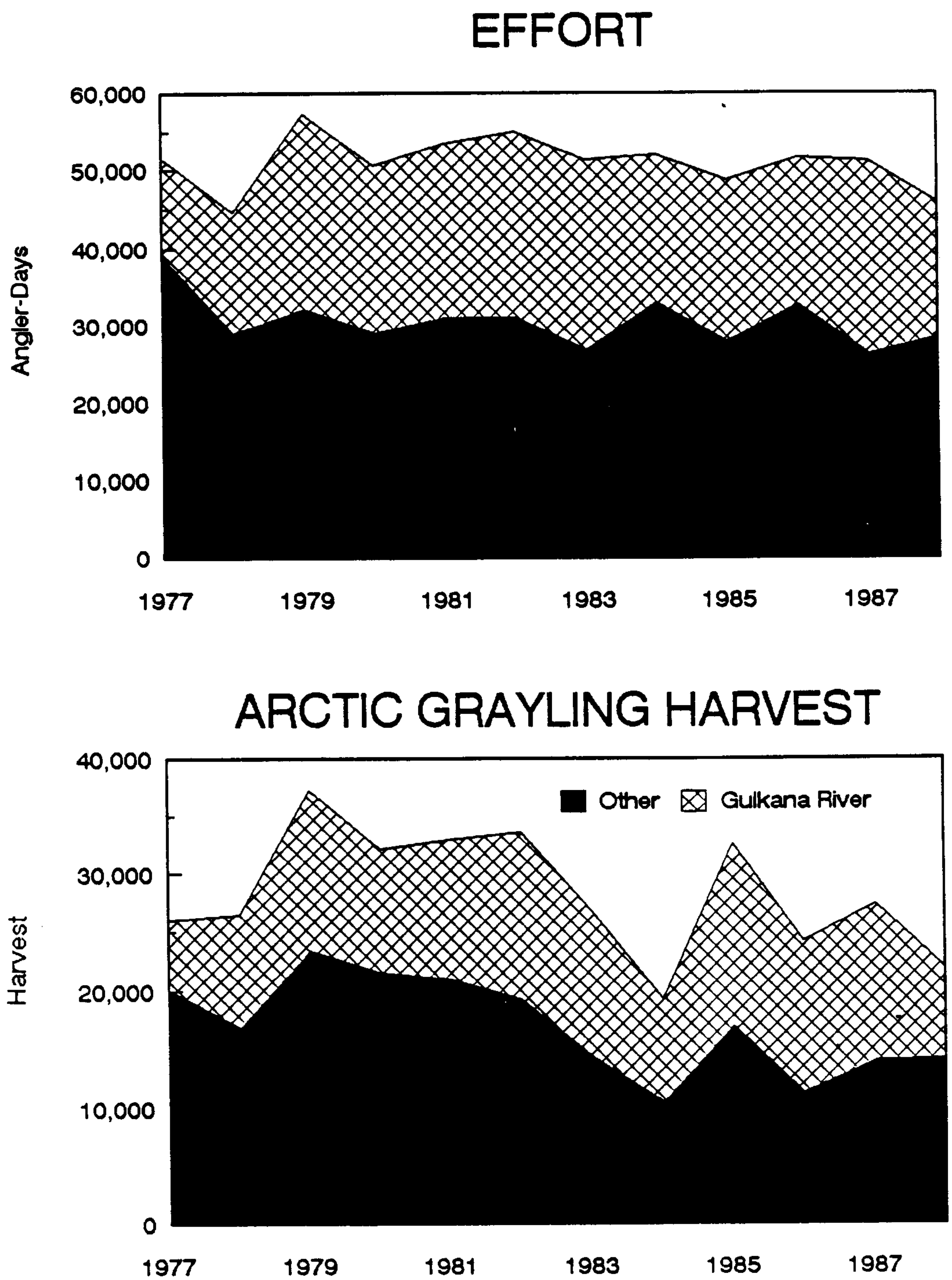


Figure 1. Recreational angler effort and harvest of Arctic grayling in the Gulkana River and Glennallen area, 1977 through 1988.

out of the summer feeding areas in the fall to lakes, deep pools, or larger river systems to overwinter (Tack 1980, Behlke et al. 1988). This migration, triggered by decreasing flows and water temperatures, generally begins in September but may extend into December (Roguski and Tack 1970). Tack (1980) pointed out that Arctic grayling may have specific spawning sites which they spawn in annually and may home to return to the same river sections annually.

A research program was begun in 1986 to evaluate the status and compositions of the stocks of the Arctic grayling in the Gulkana River (Roth and Delaney 1987). The goal of the research program is the construction of a data base of selected fishery statistics and population parameters that can be used to develop a management plan for the Gulkana River recreational fisheries that maintains the high quality of this fishery. Population structure and abundance information for Arctic grayling in the Gulkana River will provide the data base necessary to formulate long-term management strategies. As an initial step in this plan, bag and possession limits for Arctic grayling in the Gulkana River were reduced for the 1989 season from ten to five fish, only one of which can be 356 mm (14 inches) or greater in length.

The research efforts during the first year were directed toward the development of methodologies suitable to study Arctic grayling in the Gulkana River (Roth and Delaney 1987). Subsequent research efforts have been directed towards assessing population parameters, growth, and migrations for Arctic grayling in the Gulkana River (Roth and Alexandersdottir in preparation). Arctic grayling spawning populations in two major spawning tributaries of the Gulkana River, Sourdough and Poplar Grove Creeks, were surveyed and tagged in the spring and tagging/recovery efforts were conducted in study reaches of the mainstem Gulkana River to estimate the abundance of Arctic grayling and their movements.

These second-phase research efforts suggest that Arctic grayling in the Gulkana River undergo intensive migrations. Arctic grayling, which spawned in Sourdough and Poplar Grove Creeks, later redistributed throughout the Gulkana River following spawning. The recovery of tagged fish from sport anglers indicate that these migrations make an important contribution to the Gulkana River sport fishery. The migration patterns observed for Arctic grayling in the Gulkana River drainage included movement to spawning areas in the spring, the migration of fish to mainstem summer feeding areas, and the spatial segregation of fish by size and age during the summer, with larger fish found in upstream areas.

Estimates of abundance can be made using mark-recapture methods. Arctic grayling have been tagged during spawning migrations and subsequently recaptured in the mainstem study reaches. Arctic grayling were also tagged and recaptured in the mainstem study reaches. Based on these samplings, Roth and Alexandersdottir (in preparation) estimated a total abundance of about 140,000 Arctic grayling in the drainage and about 30,000 in the mainstem reach from Sourdough to the outlet of Paxson Lake. However, they cautioned that sampling was conducted in only a limited area of the drainage and that because of this no boundaries could be placed on the estimated abundance nor could assumptions of equal distributions throughout the drainage of tagged grayling be tested.

Roth and Alexandersdottir (in preparation) recommended that mark-recapture studies be continued in the Gulkana River drainage, including the operation of a weir at Poplar Grove Creek and continued mainstem samplings. These samplings will allow for comparisons to the observed migration and distribution patterns reported for Arctic grayling in the Gulkana River drainage in 1987 by Roth and Alexandersdottir (in preparation). In particular, the migrations and distributions of Poplar Grove Creek grayling can be compared to those of grayling tagged in Sourdough Creek in 1987. Poplar Grove Creek is much easier to weir and sample than Sourdough Creek given there is a permanent weir structure in place on Poplar Grove Creek. They also recommended that future studies should include a comparison of scales to otoliths to validate the present age information collected for Arctic grayling in the Gulkana River.

This report summarizes the findings of the data collection efforts during 1989. Objectives of the 1989 study were:

1. to census the number of Arctic grayling migrating into Poplar Grove, Coleman, and Bear Creeks during May 1989;

2. to estimate the age composition and mean length-at-age of Arctic grayling migrating into Poplar Grove, Coleman, and Bear Creeks in May 1989;

3. to estimate the abundance of Arctic grayling in the mainstem Gulkana River;

4. to estimate the age composition and mean length-at-age of Arctic grayling in the mainstem Gulkana River;

5. to estimate the proportion of each tagged group of Arctic grayling migrating to selected study reaches of the mainstem Gulkana River during the open water period; and,

6. to estimate the age composition of Arctic grayling harvested in the sport fishery.

METHODS

Study Area

The Gulkana River is a tributary to the Copper River. The drainage (Figure 2) includes two major tributaries to the Gulkana River, West and Middle Fork, and several smaller tributaries, the most significant of which are Sourdough Creek and Poplar Grove Creek. During the period of this study, a weir was placed on Poplar Grove Creek and sampling was carried out in the mainstem portion of the river. The mainstem was divided into three major study reaches, these being:

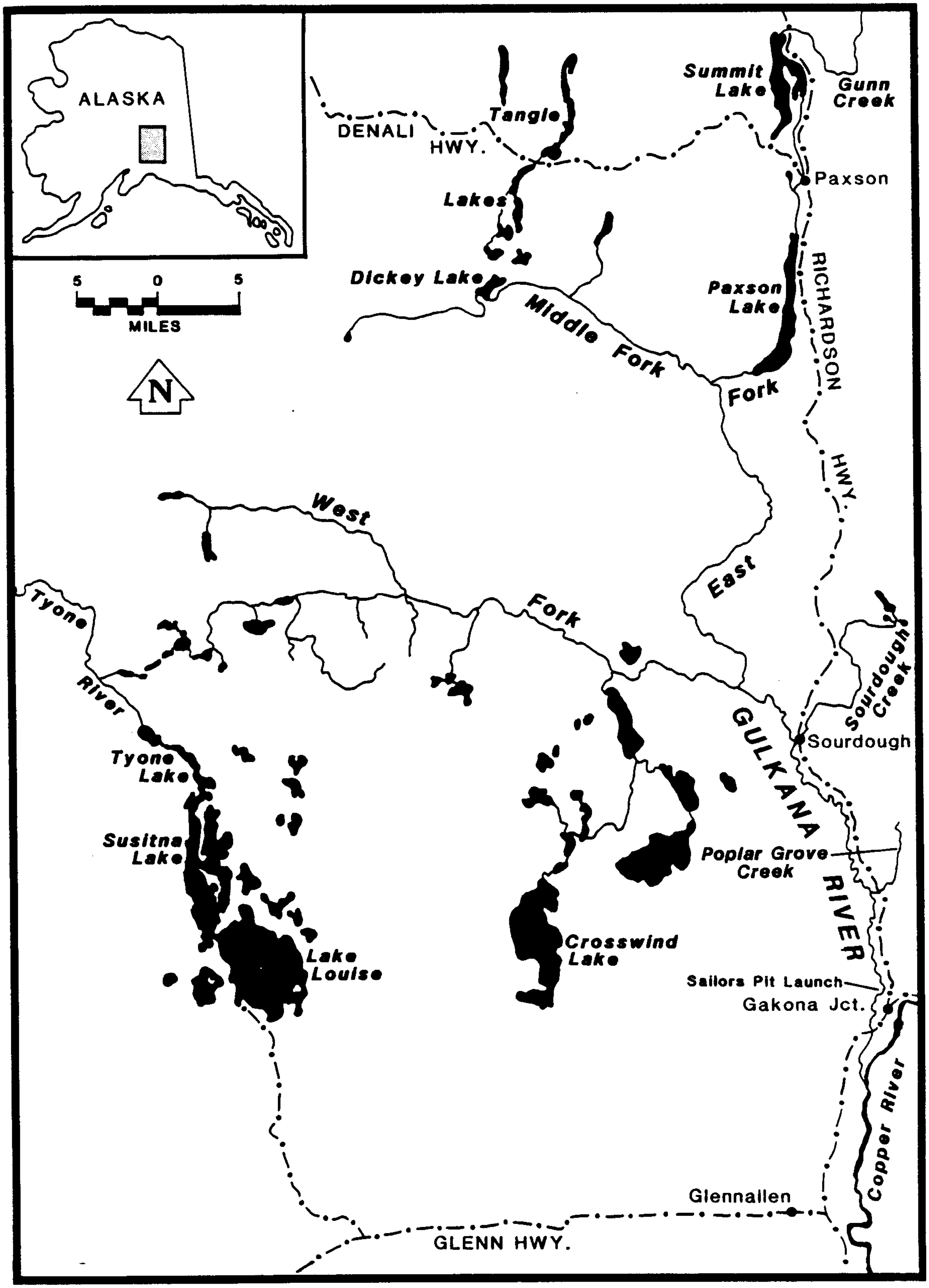


Figure 2. Map of the Gulkana River drainage.

1. Lower River reach: from the mouth of Poplar Grove Creek downstream to the mouth of the Gulkana River,

2. Sourdough reach: from 1 mile upstream of the confluence with the West Fork downstream to the mouth of Sourdough Creek, and

3. Float reach: from the outlet of Paxson Lake downstream to 1 mile above the West Fork.

The reach from Poplar Grove Creek to Sourdough Creek was not sampled during 1989 based on low numbers of captures in this area during previous samplings, and difficulty in sampling due to low water (Roth and Alexandersdottir, in preparation).

Sampling Design and Data Collection

Arctic grayling were sampled using a variety of collection techniques during 1989. For this report, adult Arctic grayling are fish that were 200 mm fork length (tip of snout to fork of tail) or longer while juvenile grayling are all fish less 200 mm fork length.

Arctic grayling were collected using seines at a weir placed in Poplar Grove Creek (Mile 138 of the Richardson Highway) approximately 91 meters above the Richardson Highway bridge from 5 May through 22 May 1989. We also attempted to place weirs in Bear, Coleman, and Sourdough Creeks; however, due to high water and icing conditions, these attempts were unsuccessful. Young-of-the-year (YOY) Arctic grayling were also sampled in Poplar Grove Creek using electrofishing gear on 18 September 1989.

Surveys using hook and line and electrofishing gear were conducted during 1989 in the Sourdough reach of the mainstem from 6 June through 18 October, the Float reach from 21 June through 14 September, and the Lower reach on 18 October. In the Float area, a combination of hook and line and backpack shocking techniques were used to collect Arctic grayling. Hook and line gear used were a combination of standard spinning and fly equipment. The electrofishing gear was a standard Coffelt Model BP-1C backpack electrofishing unit which provided power to a 3.048 m (10 ft) boom with three suspended electrodes on a 4.9 m (16 ft) riverboat. In the system, the boat acted as the cathode and the electrodes served as the anode. Power to the electrodes was controlled by a foot switch. The samplings during these surveys were conducted as the survey progressed downstream such that no reach was resampled during any one survey.

Boat electrofishing gear was used to sample the Sourdough and Lower River reaches. The electrofishing gear consisted of a Coffelt Model VVP-3C unit powered by a 3.5 kilowatt Homelite generator using pulsed DC (direct current) and a variable voltage system. The voltage was adjusted, depending on water conductivity, to maintain approximately 2 amps of output to minimize fish injury while maintaining catch rates. The unit was equipped with a 3.7 m (12 ft) boom with suspended electrodes mounted in a 6.1 m (20 ft) riverboat. Various electrodes were used including suspended 3/4 inch steel cables and a 457 mm (18 in) diameter steel globe. In the system, the boat acted as the cathode and the electrodes served as the anode. Power to the electrodes was controlled by a foot switch. The samplings during these surveys were conducted as the survey progressed downstream such that no reach was resampled during any one survey.

The fork length of all collected Arctic grayling was obtained to the nearest 1 millimeter and recorded. All adult Arctic grayling collected that did not have a previous mark were tagged with an individually numbered Floy anchor tag (style FD 68B) and released (Appendix A1). The tag numbers of all previously marked Arctic grayling were recorded and the fish released. The number of juvenile Arctic grayling collected were also recorded and these fish released unmarked. Scales were collected from a random sample of the Arctic grayling collected. One scale from each sampled Arctic grayling was collected from the preferred area[1] and mounted on a gummed card. Scales were thermohydraulically pressed against acetate cards. Resulting impressions were projected on a microfiche reader for age determination.

Data Analyses

The numbers of adult and juvenile Arctic grayling collected and tags recaptured, mean length, length distributions, age compositions, and mean length-at-age were summarized by sampling event. A sampling event is defined as sampling occurring within a specific temporal period in one study reach and with one gear type. For instance, sampling with electrofishing gear in the Sourdough reach during June is one sampling event.

Tag Ratios by Release and Recovery:

Tagged fish were released and recaptured during subsequent sampling events. The distribution of the recoveries provides information on the migrational behavior of Arctic grayling between years and over the sampling season. The choice of appropriate estimators for determining the abundance of Arctic grayling in the Gulkana River depends on the results of an analysis of tag recapture rates. In Roth and Alexandersdottir (in preparation), loglinear methods for categorical data (Agresti 1984) were used to test whether the rate of tag recovery was associated with time or location of the recovery event for each release. Because of small sample sizes during several temporal strata during 1989, these methods could not be employed. Instead, chi-square statistics were used to test the hypothesis that there were no differences between recovery locations and sampling events for each release. The chi-square tests were conducted at an alpha level of 0.10. The chi-square tests were performed using the CHISQUARE module of the software package MINITAB (MINITAB 1988).

Length Distributions:

Sampling was conducted over several locations and times using several gear types. Lengths were taken from nearly all tagged fish and in most sampling

[1] The left side of the fish approximately two rows above the lateral line and on the diagonal row downward from the posterior insertion of the dorsal fin (Clutter and Whitesel 1956).

events all fish were measured. The length data were summarized by location, time of sampling, and gear type. In order to test whether there were any differences among locations within a month or sampling events within locations and between gear types within a location, the length distributions were compared between gear types, times and locations where the data were available. A comparison of the length distribution of tags released and those recaptured within a sampling event (2 days to 2 weeks) were used to test the hypothesis of gear selectivity, as growth occurred between sampling events. For all of these comparisons, a Kolmogorov-Smirnov statistic (Sokal and Rohlf 1969) was used to compare the length distributions between the two groups at an alpha level of 0.05.

Age Composition and Mean Length-At-Age:

The age compositions of the Arctic grayling sampled at the weir in Poplar Grove Creek and during the mainstem Gulkana River electrofishing and hook and line surveys were estimated. Letting p_{hi} equal the estimated proportion of age class h in stratum i, the variance of p_{hi} was estimated by (Scheaffer et al. 1979):

$$V(\hat{p}_{hi}) = \hat{p}_{hi}(1-\hat{p}_{hi})/(n_{Ti}-1), \tag{1}$$

where, n_{Ti} is the number of legible scales read from samples collected during stratum i.

Heads of sport harvested Arctic grayling were collected at all major access sites to the Gulkana River. Otoliths were removed from all collected heads and used to determine the age composition of the sport harvest of Arctic grayling in the Gulkana River using methods described above.

Mean length-at-age was estimated by:

$$\bar{l}_a = \frac{\sum_{i=1}^{n_a} l_{ai}}{n_a} \tag{2}$$

where:

$\bar{l}_a$ = mean length at age a,

l_{ai} = length of i<u>th</u> fish at age i, and

n_a = number of fish at age a.

The variance of $\bar{l}_a$ was estimated by:

$$\text{Var } \bar{l}_a = 1/n_a \sum_{i=1}^{n_a} (l_{ia}-\bar{l}_a)^2/(n_a-1) \tag{3}$$

The hypothesis that the age compositions were independent, i.e. the same for the surveys in the Float and Sourdough reaches in the months June through August, was tested using chi-square tests. In addition, age compositions were compared between the samples taken at the weirs in May and the mainstem river samples during the month of June. These chi-square tests were conducted at an alpha level of 0.05. Chi-square tests were performed using the CHISQUARE module of the software package MINITAB (MINITAB 1988).

Analysis of variance methods were used to test the hypothesis that there were no differences in mean length-at-age between reaches and months of sampling when controlling for age and that there was no interaction between these two factors. The analysis was carried out separately for each age group using the SAS GLM procedure for general linear models (SAS 1987). The tests were conducted at an alpha level of 0.05.

Growth Increments:

The growth increments were calculated in millimeters for all Arctic grayling recaptured during 1989. Two variables typically influence the growth of grayling: 1) initial length, and 2) time at large. A multiple regression was used to determine the relationship of these variables to the observed growth increments. The REGRESS module of the software package MINITAB (MINITAB 1988) was used to carry out this regression.

Comparison of Ages by Otolith and Scale Reading:

Scales and otoliths from 52 Arctic grayling were aged and compared to validate age statistics from Gulkana River Arctic grayling determined by aging scales. Each scale and otolith was read three times by one reader. The mean age was compared to determine the difference in age between the two methods.

Abundance Estimates:

Two possible estimators were considered. First, a Petersen model could be fit to the recovery of tags released at the Poplar Grove Creek weir in 1989 in all subsequent samples taken in the mainstem river to estimate the total abundance of the population in the mainstem Gulkana River.

Abundance, $\hat{N}$, using the Petersen estimator would be estimated as (Seber 1982):

$$\hat{N} = \frac{(M+1)(C+1)}{(R+1)} - 1 \tag{4}$$

and the variance as:

$$\mathrm{Var}(\hat{N}) = \frac{(M+1)(C+1)(C-R)(M-R)}{(R+1)^2(R+2)} \tag{5}$$

where:

- M = number of tagged grayling released at the weir,
- R = number of recaptures in one or more sampling events, and
- C = number of grayling examined for recaptures in one or more sampling events.

Assumptions for this estimator are:

1. the population is closed; i.e., there is no immigration or emigration between sampling events;

2. tagging does not affect the catchability of the grayling;

3. the grayling tagged at Poplar Grove Creek have distributed evenly throughout the population prior to the recapture sample; and,

4. there is no tagging mortality and all tags are reported.

Secondly, Arctic grayling were tagged, released, and recaptured in all mainstem sampling events and these releases could also be used for estimating population size within specific sampling reaches. Analysis of recapture rates in 1987 showed that there is migration between sampling reaches precluding the use of the Petersen estimator (Roth and Alexandersdottir in preparation), but a stratified estimator which allows movement between strata can be used (Darroch 1961). When there are equal numbers of release and recovery strata, the stratified estimator ($\underline{W}$) is (Seber 1982):

$$\underline{W} = D_u M^{-1} \underline{a} \tag{6}$$

where:

- $\underline{W}$ = a vector with the estimates of the number of untagged fish in each recovery stratum,

- D_u= a diagonal matrix of the number of untagged fish observed in each recovery stratum j,

- M = a matrix of m_{ij}, the number of tagged fish in each recovery stratum, j, which were released in tagging stratum i, and

- $\underline{a}$ = a vector of the number of tagged fish released in tagging stratum i.

The number of Arctic grayling in each stratum at the time of recovery is the sum of the estimated number of untagged fish present and the number of tagged fish released in that stratum. The variance-covariance matrix of $\underline{W}$ was estimated as (Seber 1982):

$$E[(W-W)(W-W)']=D_w B^{-1} D_u D^{-1}{}_a B'^{-1} D_W + D_W(D_p-I) \tag{7}$$

where:

D_W = diagonal matrix of estimated abundance in each stratum,

D_q = diagonal matrix of reciprocals of p_i, which is the estimated probability of an animal surviving and being caught,

B = matrix of β_{ij}, the probability that a member of a_i is in stratum j at sampling and that it is alive,

and where:

$$\underline{\rho} = M^{-1}\underline{a} \quad (8)$$

$$B = D^{-1}{}_a M D_q \quad (9)$$

The variance of the point estimate for the total number of Arctic grayling present is the sum of the variance and covariance estimates for the individual strata.

Assumptions necessary for these abundance estimates are (Seber 1982):

1. all Arctic grayling in the j^{th} recovery stratum, whether tagged or untagged, have the same probability of being caught;

2. tagged fish behave independently of one another with regard to moving among strata and being caught;

3. a tagged fish is as likely to be caught as an untagged fish;

4. all tagged fish are recognized as such during recovery;

5. there is no marking induced mortality; and,

6. the population is closed; i.e., there is no immigration into or emigration from the defined strata during the duration of the study.

RESULTS

Sampling

During 1989, 10,092 Arctic grayling were collected in the Gulkana River drainage (Table 1). Of these, 4,227 were collected at a weir, 4,328 were collected using electrofishing gear, and 1,537 were collected using hook and line gear. A total of 9,298 of the collected Arctic grayling were adults and 794 were juveniles. Of the 9,298 adults collected, 1,876 had been previously marked. The remaining 7,422 adult Arctic grayling were marked with an individually numbered Floy anchor tag.

Table 1. Summary of sampling efforts conducted in the Gulkana River drainage during 1989.

Sample Reach	Gear	Total Caught	Juv.[a] Total Caught	Adults[b] Total Caught	Adults[b] Total Tagged	Adults[b] Total Recap'd
Poplar Grove Creek[c]	Weir	4,227	183	4,044	2,732	1,312
	Electro	29	29	0	0	0
	Both	4,256	212	4,044	2,732	1,312
Sourdough Reach[d]	Electro	3,187	455	2,732	2,398	336
	Hook & Line	48	0	48	39	9
	Both	3,235	455	2,780	2,435	345
Float Reach[e]	Electro	1,052	51	1,001	888	113
	Hook & Line	1,489	76	1,413	1,307	106
	Both	2,541	127	2,414	2,195	219
Lower River Reach[f]	Electro	60	0	60	60	0
All	Weir	4,227	183	4,044	2,732	1,312
	Electro	4,328	535	3,793	3,344	449
	Hook & Line	1,537	76	1,461	1,346	115
	Both	10,092	794	9,298	7,422	1,876

[a] Arctic grayling < 200mm.
[b] Arctic grayling ≥ 200mm.
[c] Poplar Grove Creek sampled by weir from 5/05-5/18 and by electrofishing on 9/18.
[d] Sourdough reach sampled on 6/6-6/13, 7/13-7/18, 8/21-8/28, 9/26-10/04, and 10/11-10/15.
[e] Float reach sampled on 6/21-6/29, 7/27-8/05, 9/12-9/19, and 10/13.
[f] Lower River reach sampled on 10/18.

A total of 4,227 Arctic grayling (4,044 adults and 183 juveniles) were collected in Poplar Grove Creek from 5 May through 18 May 1989. Of the 4,044 adult Arctic grayling, 1,312 had been previously marked with a tag. The 2,732 adult Arctic grayling that did not have a mark were marked with individually numbered Floy anchor tags. In addition, 29 YOY Arctic grayling were collected using electrofishing gear in Poplar Grove Creek on 18 September 1989. None of the 212 juvenile Arctic grayling collected were marked with a tag. The count of upstream migrating Arctic grayling in Poplar Grove Creek during 1989 is believed to be a near complete count. A small number (likely less than 100 grayling) were believed to have migrated upstream before the weir was in place.

A total of 3,235 Arctic grayling (2,780 adults and 455 juveniles) were collected in the Sourdough reach from 6 June through 18 October 1989. Of the 2,780 adult Arctic grayling, 345 (12.4%) had been previously marked with a tag. The 2,780 adult Arctic grayling that did not have a mark were marked with individually numbered Floy anchor tags. None of the 455 juvenile Arctic grayling collected were marked with a tag.

A total of 2,541 Arctic grayling (2,414 adults and 127 juveniles) were collected in the Float reach from 21 June through 13 October 1989. Of the 2,414 adult Arctic grayling, 219 (9.1%) had been previously marked with a tag. The 2,195 adult Arctic grayling that did not have a mark were marked with individually numbered Floy anchor tags. None of the 127 juvenile Arctic grayling collected were marked with a tag.

Sixty (60) Arctic grayling (all adults) were collected in the Lower River reach on 18 October 1989. None of the 60 adult Arctic grayling collected had been previously marked with a tag and all were marked with individually numbered Floy anchor tags.

Migration

A total of 1,312 Arctic grayling were recaptured at the Poplar Grove weir during 1989[2] (Table 1). Of these, 1,306 (94.4%) had originally been tagged in Poplar Grove Creek, of which 1,272 (97.4%) were tagged during 1988.

Of the 4,044 Arctic grayling tagged and released in Poplar Grove Creek during 1989, 89 were recaptured during subsequent mainstem surveys (Table 2). Sixty-one (61) of these recaptures (68.5%) occurred in the Sourdough reach, of which 32 (52.5%) occurred during June, 10 (16.4%) during July and August, and 19 (31.1%) during September and October. The remaining recoveries were recorded from the Float area (Table 2).

The majority of the recoveries of Arctic grayling tagged in the mainstem during 1989 were made in the same reach where the fish were first released. Of the 5,194 adult Arctic grayling tagged and released during 1989 in the Sourdough and Float reaches (Tables 3 and 4), 262 (5.0%) were recaptured one

[2] Because 71 of the 1,312 recaptured grayling have been recovered several times during their tagging history, the recaptured grayling have a possible 1,383 original tagging sites (Appendix A2).

Table 2. Recaptures of Arctic grayling tagged at the weir on Poplar Grove Creek during 1989.

Reach	Location	June	July-Aug	Sept-Oct	All
Sourdough	1 Mile Above West Fork to Poplar Grove Creek[a]	32 (892)	10 (243)	19 (1,645)	61 (2,780)
Float	Falls to 1 Mile Above the West Fork	6 (193)	2 (92)	0 (21)	8 (306)
	Middle Fork to Falls	6 (772)	10 (809)	1 (270)	17 (1,851)
	Paxson Lake Outlet to Middle Fork	2 (159)	1 (75)	0 (23)	3 (257)
All		46 (2,016)	23 (1,219)	20 (1,959)	89 (5,194)

[a] Numbers in () are the number of adult grayling examined for tags.

or more times during sampling in the mainstem Gulkana River. Of the 262 recaptures, 198 (75.6%) of the recaptures were recorded in the same area of release.

Of the 64 Arctic grayling recaptured at sites other than the area of release, 36 (56.3%) had traveled to an upstream reach before recapture. Most of the downstream migration was observed for fish which had been tagged in the Float reach during the summer and were then recaptured in the Sourdough reach during the fall sampling. The greatest migration distance recorded for Gulkana River tagged Arctic grayling was for fish which had migrated between Poplar Grove Creek and the outlet of Paxson Lake (Figure 2).

Tag Ratios by Release and Recovery

The tagged grayling released at Poplar Grove Creek during May were recovered in the Float and Sourdough areas during all subsequent mainstem sampling events (Table 3). In all months, the percent tagged in the recovery samples was higher in the Sourdough reach compared to the Float reach (Table 3). These differences were significant for the June and July/August sampling events, but not for the September sampling events (Table 4). The percent tagged in the samples did not differ significantly between June and July/August within either reach, but did decrease significantly in September in the Sourdough reach but not in the Float reach (Tables 5 and 6).

The tagged grayling released in the Sourdough and Float reaches were recaptured in subsequent sampling over the summer (Tables 5 and 6). In both reaches the majority of tags were recovered in the release area (Table 5 and 6), however, fish from all releases exhibited migration between reaches. This was particularly evident for the grayling tagged in June, which were recovered in equal proportions in both reaches in subsequent months (Tables 5 and 6). No significant differences were found between reaches within a month or among months within a reach when tag ratios were compared for the June release (Table 4).

These results show that the grayling tagged in Poplar Grove Creek during May were more available in the Sourdough reach during June and later in July and August compared to the Float reach. The results also show that the tag ratios for grayling released at Poplar Grove Creek during May never reached an equilibrium point for the entire study reach. In addition, the grayling tagged in the Sourdough reach migrated to the Float area, and those tagged in the Float area migrated downstream to the Sourdough reach in September.

Length Distributions

The length distributions of all sampled grayling were compared between sampling reaches and within specific reaches over months. The mean length of the captured grayling was higher in June in both the Sourdough and Float reaches, compared to samples from July (Float reach) and August (Sourdough reach). The mean lengths subsequently increased to seasonal highs in October in both the Float and Sourdough reaches (Figure 3, Table 7). The length distributions were compared among months within each reach and the changes observed in the size distributions were significant in all cases except

Table 3. Percentages of tagged grayling from Poplar Grove Creek and the June samplings in the Sourdough and Float reaches that were recovered in the Sourdough and Float reaches during subsequent sampling events, 1989.

Release Location	Recovery Month	Percent Recoveries	
		Sourdough	Float
Poplar Grove Creek	June	3.6	1.2
	July/August	4.1	1.3
	September	1.1	0.3
Sourdough - June	July/August	0.9	1.4
	September	0.4	0.9
Float - June	July/August	0.7	1.6
	September	0.5	0.6

Table 4. Comparisons of the percentages of tagged grayling by release and recovery strata in the Gulkana River during 1989.

Release Location	Recovery	χ^2	df	P
H_o: Percent tagged in recovery samples same for both releases.				
Poplar Grove Creek	June	11.4	1	< 0.005
	July/August	8.1	1	< 0.005
	September	1.8	1	> 0.100
Sourdough - June	July/August	1.8	1	> 0.100
	September	0.1	1	> 0.100
Float - June	July/August	0.7	1	> 0.100
	September	1.3	1	> 0.100
H_o: Percent tagged in recovery sample same between months.				
Poplar Grove Creek	Sourdough[a]	0.1	1	> 0.100
	Sourdough[b]	20.7	1	< 0.005
	Float[a]	> 0.1	1	> 0.100
	Float[b]	2.3	1	> 0.100
Sourdough - June	Sourdough[c]	1.3	1	> 0.100
	Float	0.4	1	> 0.100
Float - June	Sourdough[b]	0.3	1	> 0.100
	Float	1.7	1	> 0.100

[a] June and July/August recoveries.
[b] June, July/August, and September recoveries.
[c] July/August and September recoveries.

Table 5. Recaptures of Arctic grayling tagged in the Sourdough reach and recaptured in the Float and Sourdough reaches during 1989.

Recapture Reach	Tagging Month	Month of Recapture: June	July/August	September/October	Total Recaptured
Sourdough	June	28(3.1)[a]	4(1.6)	23(1.4)	57
	July/August	--	8(3.3)	9(0.5)	17
	Sept/Oct.	--	--	67(4.1)	67
Float	June	14(1.2)	15(1.7)	5(1.7)	34
	July/August	--	--	1(0.3)	1
	Sept.	--	--	1(0.3)	1

[a] Percent of fish examined with tags from this release

Table 6. Recaptures of Arctic grayling tagged in the Float reach and recaptured in the Float and Sourdough reaches during 1989.

Recapture Reach	Tagging Month	Month of Recapture: June	July/August	September/October	Total Recaptured
Float	June	25(2.2)[a]	17(1.9)	2(0.2)	44
	July/August	--	13(1.4)	2(1.0)	16
	Sept.	--	--	2(0.7)	2
Sourdough	June	1(0.1)	3(1.2)	15(0.1)	19
	July/August	--	0	8(0.5)	8
	Sept.	--	0	1(0.1)	1

[a] Percent of recovery sample with tags from this release.

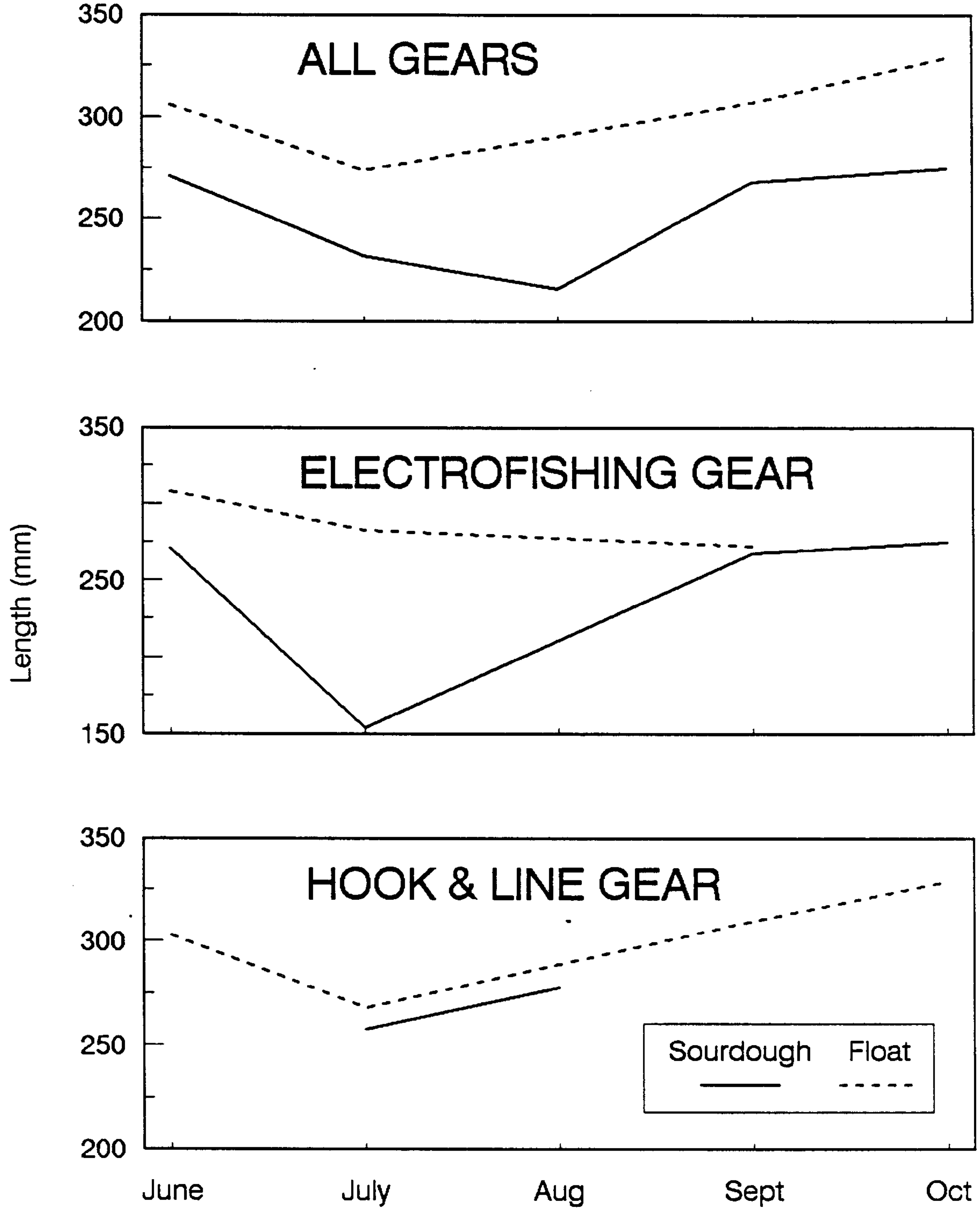


Figure 3. Mean length of Arctic grayling, by month and gear type, sampled in the Float and Sourdough reaches of the Gulkana River during 1989.

Table 7. Mean lengths of Arctic grayling, by sampling event, collected during 1989.

Study Reach	Dates	Capture Gear	Sample Size	Number Measured	Mean Length	SE	MIN	MAX
Poplar Grove Creek	5/05-5/18	Weir	4,227	4,224	258.7	0.6	101	397
	9/18	Electro	29	29	66.6	2.0	53	94
Sourdough	6/06-6/13	Electro	1,010	1,009	258.7	0.6	101	397
	7/13-7/18	Electro	7	7	154.3	8.3	122	186
	7/13-7/18	H&L	21	21	258.1	3.9	228	285
	7/13-7/18	Both	28	28	232.1	9.3	122	285
	8/21-8/28	Electro	406	406	211.4	2.9	85	385
	8/21-8/28	H&L	27	27	278.1	10.7	205	413
	8/21-8/28	Both	433	433	215.5	2.9	85	413
	9/26-10/04	Electro	1,623	1,620	267.5	1.3	49	398
	10/11-10/18	Electro	141	141	274.5	5.7	56	374
Float	6/21-6/29	Electro	606	606	308.2	1.6	144	400
	6/21-6/29	H&L	528	528	303.2	1.6	200	399
	6/21-6/29	Both	1,134	1,134	305.9	1.2	144	400
	7/27-8/05	Electro	419	418	283.4	2.6	127	398
	7/27-8/05	H&L	664	663	267.9	2.1	135	439
	7/27-8/05	Both	1,083	1,081	273.9	1.7	127	439
	9/12-9/19	Electro	27	27	271.6	15.8	127	393
	9/12-9/19	H&L	294	294	310.5	2.3	182	404
	9/12-9/19	Both	321	321	307.2	2.6	127	404
	10/13	H&L	5	5	328.6	7.7	308	349
Lower River	10/18	Electro	60	60	265.0	4.8	201	345

between September and October in the Float reach (Table 8). These findings suggest that recruitment of smaller fish into the mainstem populations occurs during June and July. The length distributions of captured grayling were significantly larger in all months for grayling sampled in the Float reach compared to the Sourdough reach (Table 8).

Two gear types (hook and line and electrofishing gear) were used in both mainstem study reaches during most months and the length distributions of the grayling captured by the two gear types were compared. In the Float reach, the length distributions of Arctic grayling captured using electrofishing gear were significantly larger than those captured using hook and line gear within any month except September when there was no significant difference between the length distributions captured by the two gear types (Table 9). In the Sourdough reach, the opposite was true. The length distributions of Arctic grayling captured using hook and line gear were significantly larger than those captured using electrofishing gear within any month (Table 9). This suggests that the larger numbers of small grayling present in the Sourdough reach were more vulnerable to capture using electrofishing gear than hook and line gear.

Selectivity of the two gear types was tested by comparing the length distributions of recaptured grayling to those released within specific sampling events. In the Float reach, the length distributions of Arctic grayling recaptured using the same gear was not significantly different than their length distributions at release in any month (Table 10). However, in the Sourdough reach during June and September/October, the length distribution of recaptured grayling using electrofishing gear was different from those released using electrofishing gear. In June, 28 recoveries were on the average smaller than the fish released that month, and in later months the recoveries were larger than the releases in the same month (Table 10). Selectivity occurred for the electrofishing gear used in the Sourdough reach during these months.

In order to test for size segregation of the tagged grayling, the length distributions of the recaptured grayling were compared between reaches within months and releases (Table 11). The length distributions of the recaptures of grayling tagged at Poplar Grove Creek and recaptured in either mainstem reach during June and July/August were not significantly different. Nor were the length distributions of the recaptures of grayling tagged and released in the Sourdough and Float reach during June and recaptured in July/August significantly different. The length distributions of recaptures of the grayling originally tagged in the Sourdough reach during June and later recaptured in the Sourdough and Float reaches were marginally significant ($P = 0.06$), suggesting that, at least in this case, larger grayling moved upstream during the summer.

Age Composition and Mean Length-At-Age

Scale samples were collected during the May sampling at the weir on Poplar Grove Creek and during the June, July, and August sampling of the Sourdough

Table 8. Comparison of length distributions of Arctic grayling sampled from the Sourdough and Float reaches of the Gulkana River during 1989.

Comparison				
BETWEEN MONTHS				
	June-July	July-Aug.	Aug.-Sept.	Sept.-Oct.
Sourdough Reach				
Mean Length (mm)	271 - 232	232 - 216	216 - 268	268 - 275
P-Value[a]	0.0000	0.0020	0.0000	0.0004
	June-July	July-Sept.		Sept.-Oct.
Float Reach				
Mean Length (mm)	306 - 274	274 - 307		307 - 329
P-Value[a]	0.0000	0.0000		0.0942
BETWEEN REACHES				
		Sourdough Reach-Float Reach		
June				
Mean Length (mm)		271 - 306		
P-Value[a]		0.0000		
July-August				
Mean Length (mm)		216 - 274		
P-Value[a]		0.0000		
September				
Mean Length (mm)		268 - 307		
P-Value[a]		0.0000		
October				
Mean Length (mm)		275 - 329		
P-Value[a]		0.0052		

[a] P-Values less than 0.05 are considered significant.

Table 9. Comparison of length distributions of Arctic grayling sampled from the Sourdough and Float reaches of the Gulkana River using electrofishing and hook and line gear during 1989.

Comparison			
BETWEEN GEAR TYPES			
	Electrofishing	Hook & Line	P-Value[a]
Float Reach[b]			
June	308(606)	303(528)	0.0005
July-August	283(418)	268(663)	0.0000
September	272(27)	311(294)	0.1339
Sourdough Reach[b]			
July	154(7)	258(21)	0.0010
August	211(406)	278(27)	0.0000
BETWEEN REACHES			
	Float	Sourdough	P-Value[a]
Electrofishing Gear[b]			
July-August	283(418)	210(411)	0.0000
Hook and Line Gear[b]			
July-August	268(663)	269(48)	0.0176

[a] P-Values less than 0.05 are considered significant.
[b] Numbers in () are the number of adult grayling examined for tags.

Table 10. Comparison of length distributions of Arctic grayling released and recaptured in the Sourdough and Float reaches using the same gear types and during the same months during 1989.

Reach & Month	Gear Type	Number Released	Mean Length	SE	Number Recovered	Mean Length	SE	P-Value[a]
Sourdough								
June	Electro	866	288	1.5	28	270	8.9	0.0174
July-Aug.	Electro	193	263	2.8	3	287	13.3	0.1476
Sept-Oct.	Electro	1,580	277	1.1	67	292	4.8	0.0000
Float								
June	Electro	583	310	1.5	14	311	8.7	0.2942
	H&L	517	303	1.6	11	323	7.2	0.1038
July-Aug.	Electro	381	293	2.2	5	282	24.4	0.3366
	H&L	587	280	1.9	8	283	14.7	0.4883
Sept-Oct.	H&L	295	312	2.3	2	307	15.0	0.3930

[a] P-Values less than 0.05 are considered significant.

Table 11. Comparison of length distributions of Arctic grayling recaptured between reaches in the Gulkana River during 1989.

		RECAPTURE REACH						
		Sourdough Reach			Float Reach			
Release Site	Recapture Month	Sample Size	Mean Length	SE	Sample Size	Mean Length	SE	P-Value[a]
Poplar Grove Weir								
	June[b]	32	296	5.4	14	292	7.3	0.3608
	July-Aug[b]	10	312	33.5	13	304	6.9	0.1342
Sourdough Reach								
	June[b]	4	253	7.9	15	297	12.4	0.0583
Float Reach								
	June[b]	3	309	26.0	17	299	9.7	0.4342

[a] P-Values less than 0.05 are considered significant.
[b] Recaptures by all gear types were used as there were no significant ($P < 0.05$) differences in the length distributions by gear type.

and Float reaches. Summaries of age composition and mean length-at-age for these samplings are presented in Tables 12 through 14.

Comparison of Age Composition:

Arctic grayling sampled in the Float and Sourdough reaches were from 0 through 8 years old, with age classes 2, 3, 4, and 5 comprising the largest percentage of the fish sampled in each of the reaches. Arctic grayling sampled from Poplar Grove Creek were from 0 through 7 years old, with age classes 3, 4, and 5 comprising the largest percentage of the fish sampled in the creek. A portion of the age 3 grayling collected at the weir were observed to be sexually mature which is younger than that reported for other Alaska river systems (Ridder 1989, Tack 1980).

There were significant differences in the age compositions of Arctic grayling sampled in the Float and Sourdough reaches from June to July/August (Table 15). The June samples contained a higher proportion of older age classes whereas the July/August samples contained a higher proportion of younger age classes (Figure 4). This suggests either immigration of young fish or growth recruitment into the mainstem populations during July/August. There was also a significant difference in age compositions of Arctic grayling in samples collected during June and July/August from each of the two mainstem study reaches (Table 15). The Float reach had a higher proportion of older age classes than the Sourdough reach during both the June and July/August samplings (Figure 4). There were also significant differences in age compositions of fish tagged at the Poplar Grove weir during May and observed in the Float and Sourdough reaches during June (Table 15). There was a higher proportion of younger age classes in the Sourdough reach than at the weir whereas in the Float reach there was a higher proportion of older age classes than at the weir (Figure 4). The segment of the population of grayling that inhabits the Float reach is apparently older than that present in the Sourdough reach.

Comparison of Mean Length-At-Age:

The mean length-at-age was compared between the Poplar Grove Creek weir samples taken in May and the samples from the two mainstem reaches in June. The analyses of variance showed significant differences in the mean length-at-age of the Arctic grayling sampled at the Poplar Grove weir in May and those sampled from both the Float and Sourdough reaches during June (Table 16). In both cases, the mean length-at-age of the grayling sampled from the mainstem reaches during June were larger than those observed at the Poplar Grove weir (Figure 5).

There were no significant differences in the mean length-at-age (Table 15) of the Arctic grayling sampled from the Float reach between the June and July/August sampling (Figure 5). In the Sourdough reach there was significant interaction between age and month, in that mean length-at-age was smaller in June for ages 2-4, but larger for the older classes. There were, however, significant differences in the observed mean length-at-age of the Arctic grayling sampled between the reaches within both the June and the July/August samplings (Table 16). For the July/August sampling, the grayling

Table 12. Age composition and mean length-at-age statistics for Arctic grayling collected in Poplar Grove Creek during 1989.

Parameter	Age Class								
	1	2	3	4	5	6	7	8	All
<u>Age Composition</u>									
Percent	3.7	2.5	20.7	47.2	19.5	5.1	0.8	0.0	100.0
Standard Error	0.9	0.7	1.8	2.3	1.8	1.0	0.4	---	---
Sample Size	18	12	101	233	95	25	4	0	488
<u>Mean Length-at-Age</u>									
Mean	142	155	228	255	285	305	313	---	252
Standard Error	3.6	4.5	2.7	1.3	2.5	4.5	18.8	---	1.9
Sample Size	18	12	101	233	95	25	4	0	488

Table 13. Age composition and mean length-at-age statistics for Arctic grayling collected in the Float reach during 1989.

Parameter	1	2	3	4	5	6	7	8	All
	Age Class								
<u>Age Composition</u>									
June:									
Percent	0.0	2.9	23.0	21.8	35.1	14.9	2.3	0.0	100.0
Standard Error	---	1.3	3.2	3.1	3.6	2.7	1.1	---	---
Sample Size	0	5	40	38	61	26	4	0	174
July-August:									
Percent	17.6	21.1	20.1	20.1	14.1	5.0	1.5	0.5	100.0
Standard Error	2.7	2.9	2.9	2.9	2.4	1.6	0.9	0.5	---
Sample Size	35	42	40	40	28	10	3	1	199
<u>Mean Length-at-Age</u>									
June:									
Mean	---	225	270	295	318	327	335	---	301
Standard Error	---	5.2	5.7	4.0	3.0	4.7	13.5	---	2.8
Sample Size	0	5	40	38	61	26	4	0	174
July-August:									
Mean	169	212	264	303	317	345	357	397	257
Standard Error	2.9	4.4	4.6	4.6	4.2	8.3	16.8	---	4.5
Sample Size	35	42	40	39	28	10	3	1	198

Table 14. Age composition and mean length-at-age statistics for Arctic grayling collected in the Sourdough reach during 1989.

Parameter	Age Class								
	1	2	3	4	5	6	7	8	All
Age Composition									
June:									
Percent	8.8	12.9	20.5	26.9	19.9	7.6	3.5	0.0	100.0
Standard Error	2.2	2.6	3.1	3.4	3.1	2.0	1.4	---	---
Sample Size	15	22	35	46	34	13	6	0	171
July-August:									
Percent	20.6	23.0	30.6	13.9	9.1	2.4	0.5	0.0	100.0
Standard Error	2.8	2.9	3.2	2.4	2.0	1.1	0.5	---	---
Sample Size	43	48	64	29	19	5	1	0	209
Mean Length-at-Age									
June:									
Mean	136	193	245	277	325	340	334	---	263
Standard Error	5.5	4.7	5.9	4.8	4.8	6.6	10.4	---	5.1
Sample Size	15	22	35	46	34	13	6	0	171
July-August:									
Mean	167	216	258	282	304	336	314	---	239
Standard Error	3.2	3.4	2.8	5.1	6.8	29.7	---	---	4.1
Sample Size	43	48	64	29	19	5	1	0	209

Table 15. Comparison of age composition statistics for Arctic grayling captured in the Sourdough and Float reaches of the Gulkana River during 1989.

Comparison	χ^2 [a]	df [b]
Within Reaches Between Months:		
Float Reach	82.46	6
Sourdough Reach	43.53	6
Within Months Between Reaches:		
June	39.18	6
July-August	12.62	6
From Poplar Grove Weir (May) Between Reaches (June):		
Sourdough Reach	53.51	6
Float Reach	59.46	6

[a] Chi-square statistic: Values > 12.59 significant at $\alpha = 0.05$.
[b] Degrees of freedom.

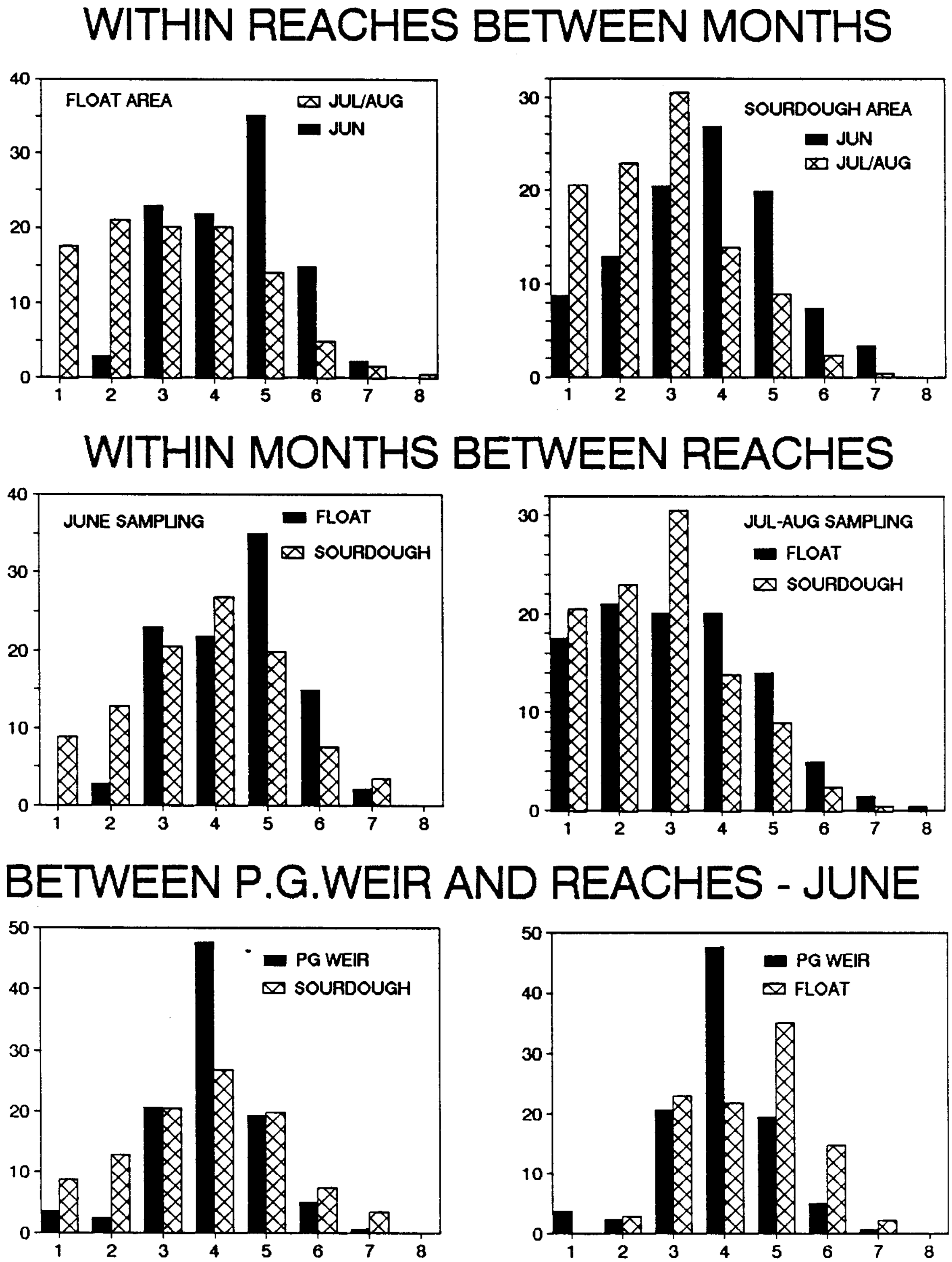


Figure 4. Comparisons of age composition statistics for Arctic grayling in the Gulkana River during 1989.

Table 16. Results of ANOVA comparing mean length-at-age for Arctic grayling collected in the Gulkana River during 1989.

Source	df	F-value	P-value
A: H_0: Mean length-at-age is the same for the Poplar Grove weir samples and the June mainstem samples.			
Age	6	295.4	0.001
Site	2	45.3	0.001
Interaction	11	4.4	0.001
B. H_0: Mean length-at-age is the same among months within a reach.			
<u>Sourdough Reach</u>			
Month	1	0.6	0.450
Age	6	212.8	0.0001
Interaction	6	4.8	0.0001
<u>Float Reach</u>			
Month	1	0.9	0.330
Age	6	142.7	0.0001
Interaction	5	1.7	0.140
C. H_0: Mean length-at-age is the same between reaches within a month.			
<u>June</u>			
Site	1	4.3	0.038
Age	6	129.0	0.0001
Interaction	5	4.7	0.0004
<u>July/August</u>			
Site	1	6.3	0.012
Age	6	266.4	0.0001
Interaction	6	1.9	0.074

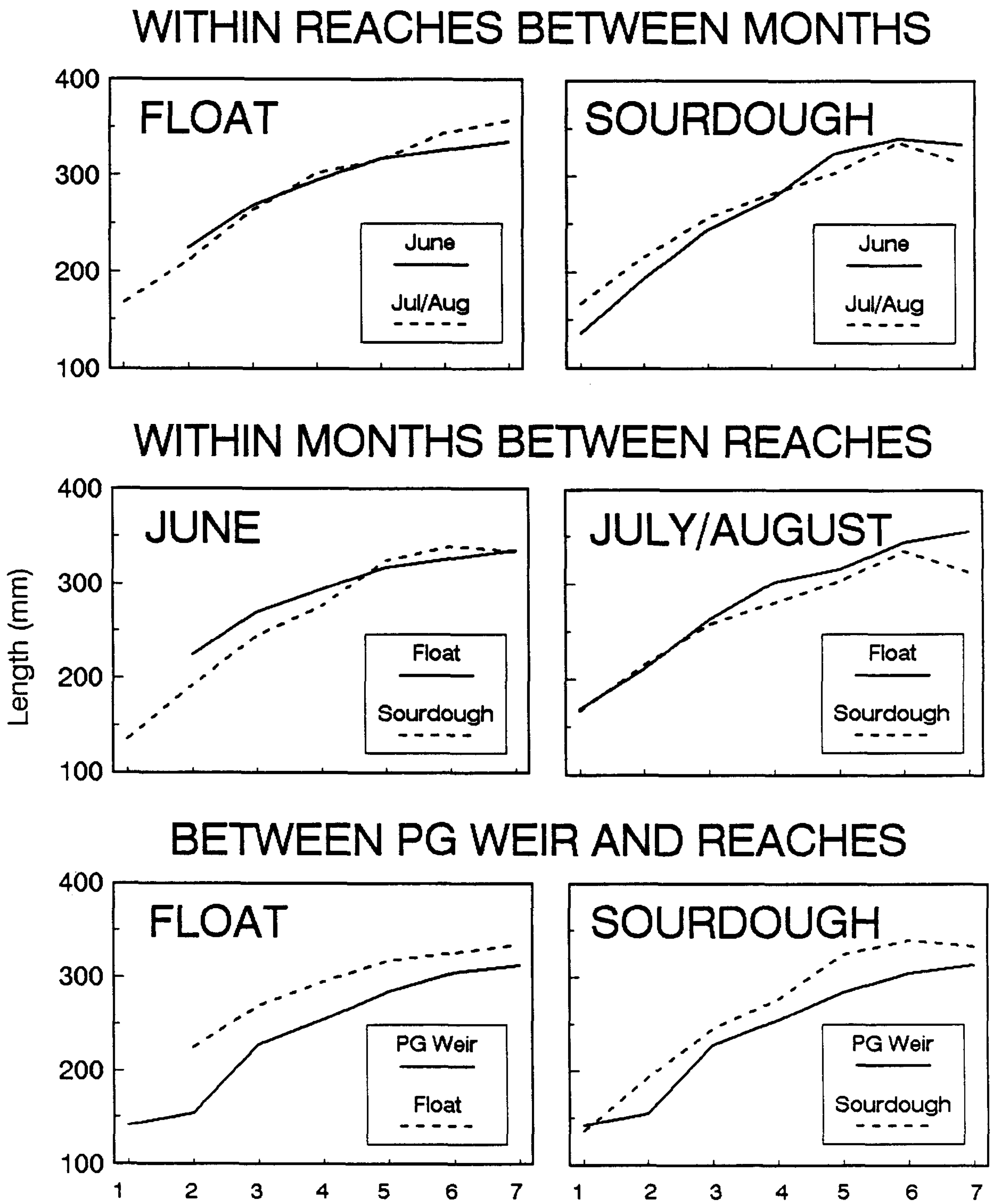


Figure 5. Comparisons of mean length-at-age statistics for Arctic grayling in the Gulkana River during 1989.

sampled from the Float reach were significantly larger at age than those sampled from the Sourdough reach (Figure 5). For the June sampling, there was also a significant difference in the observed mean length-at-age of grayling sampled from the two reaches; however, there was significant interaction between the site and age variables ($P < 0.05$). The interaction found is due to the different trends in the Sourdough reach in June, i.e. the smaller means for ages 1-3 compared to the Float reach in June or Sourdough in July/August (Figure 5). This is possibly due to the size segregation as larger grayling of these younger age classes may move upstream. Another factor may be the selectivity of the electrofishing gear for smaller fish found in the Sourdough reach during the June sampling (Table 10).

Growth Increments

One hundred and seventy-four Arctic grayling were recaptured within 30 days of their release during 1989. Since growth can be expected to be insignificant during this time frame, the observed differences between length at release and recapture can be defined as measurement error, and would be expected to equal zero. The mean error observed during 1989 was -0.4 mm (SE = 1.1 mm) and was not significantly different from zero. The error was found, however, to have a negative correlation with length at release ($r^2 = 0.06$), which although weak, was significantly different from zero ($P < 0.001$). This was due to a few outliers at the extreme ranges of small and large fish. Large positive errors only occurred for small grayling and large negative errors for large grayling (Figure 6).

Over the course of this study, 2,044 Arctic grayling have been captured and measured two or more times. These data can be used to estimate growth of Arctic grayling in the Gulkana River drainage as related to initial length and time at large. A multiple regression of these variables on growth was significant and explained 56% of the variation in the growth of the tagged grayling (Figure 7, Table 17).

During 1989, 1,206 Arctic grayling were recaptured at the Poplar Grove weir that had been released at the weir in earlier years (Appendix A2). Thirty-four of these grayling had been released during 1986 and 1,272 during 1988. From 1988 to 1989, these grayling grew an average of 21.0 mm (Figure 8). From 1986 to 1989, these grayling grew an average of 66.3 mm, or an average of 22.1 mm per year.

Comparison of Ages by Otolith and Scale Reading

Although there was variation within the repeated ages determined by reading scales and otoliths, there was little difference in the mean ages of sampled grayling determined by both methods (Table 18). Nearly 90% of the grayling aged by both methods differed in age by a factor of only ± 1 age class. Error between the two aging methods was generally greater with increasing age (Figure 9).

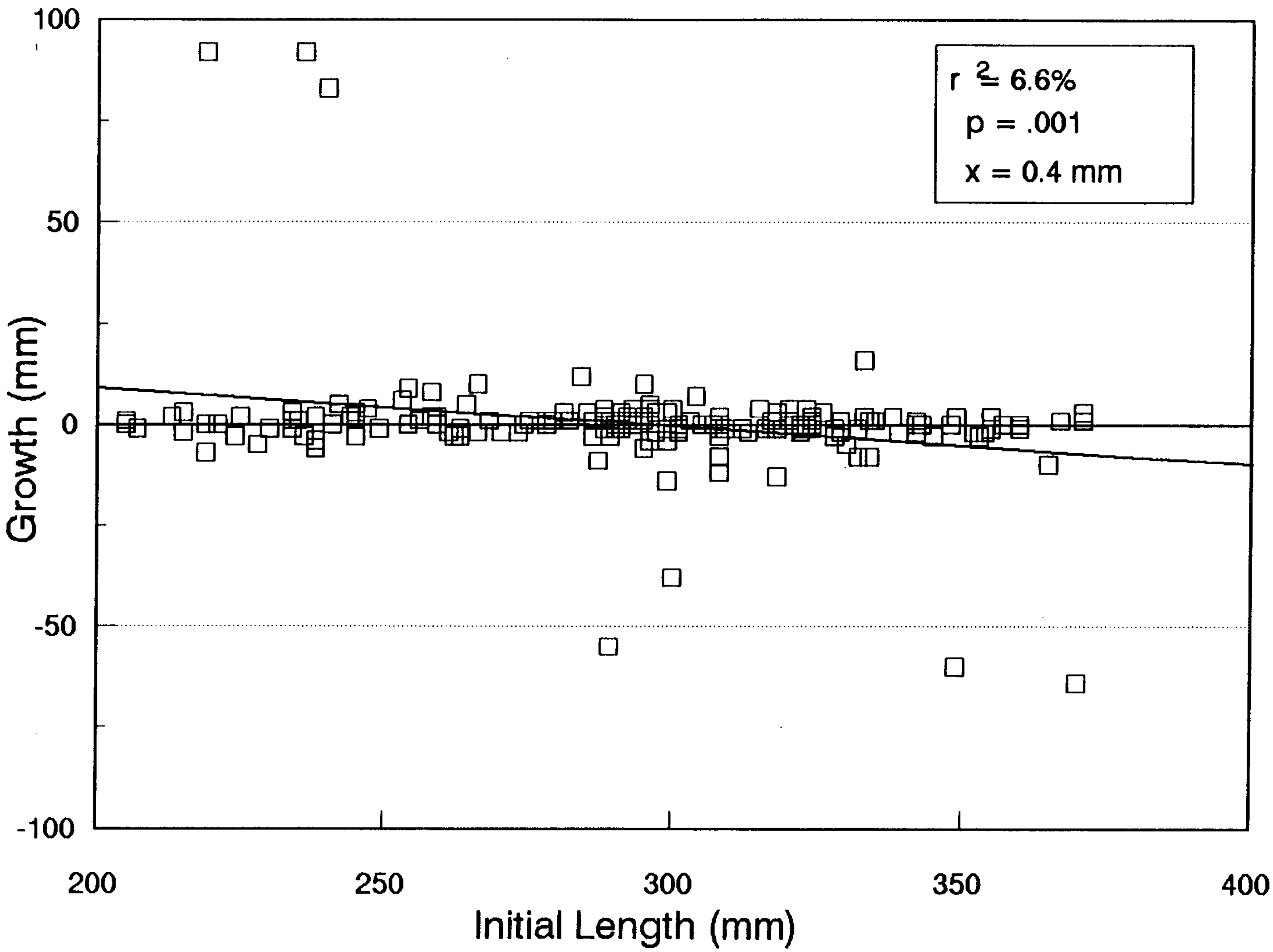
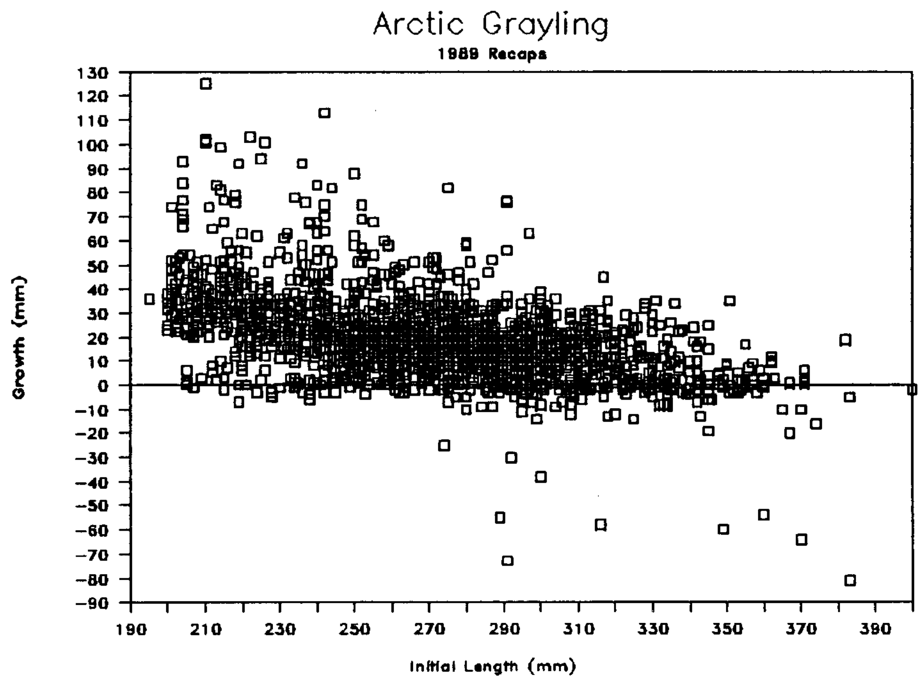


Figure 6. Error associated with the measurement of Arctic grayling in the Gulkana River during 1989.



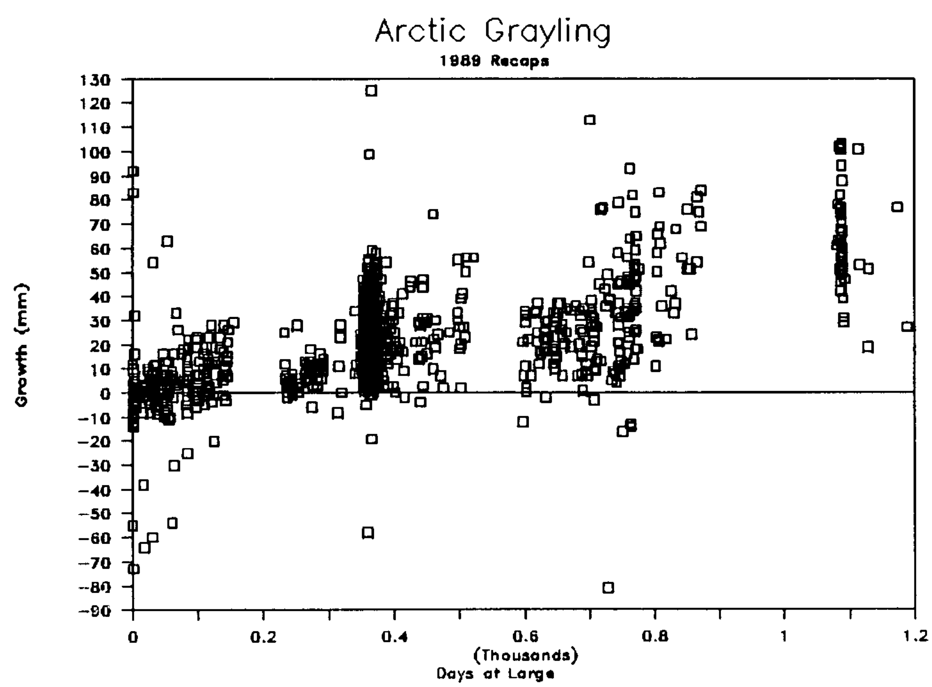


Figure 7. Relationship of the growth of Arctic grayling in the Gulkana River to initial length and time at large.

Table 17. Observed relationship between growth (G) and initial length (L_i) and days at large (t) for Arctic grayling recaptured in the Gulkana River from 1986 through 1989.

Independent Variable	Equation	Correlation Coefficient (r^2)	P-Value[a]
Initial Length	$G = 86.4 - 0.247(L_i)$	27.3%	0.0000
Days at Large	$G = 1.6 + 0.050(t)$	36.7%	0.0000
Initial Length & Days at Large	$G = 60.4 + 0.04(t) - 0.21(L_i)$	55.9%	0.0000

[a] P-Values less than 0.05 are considered significant.

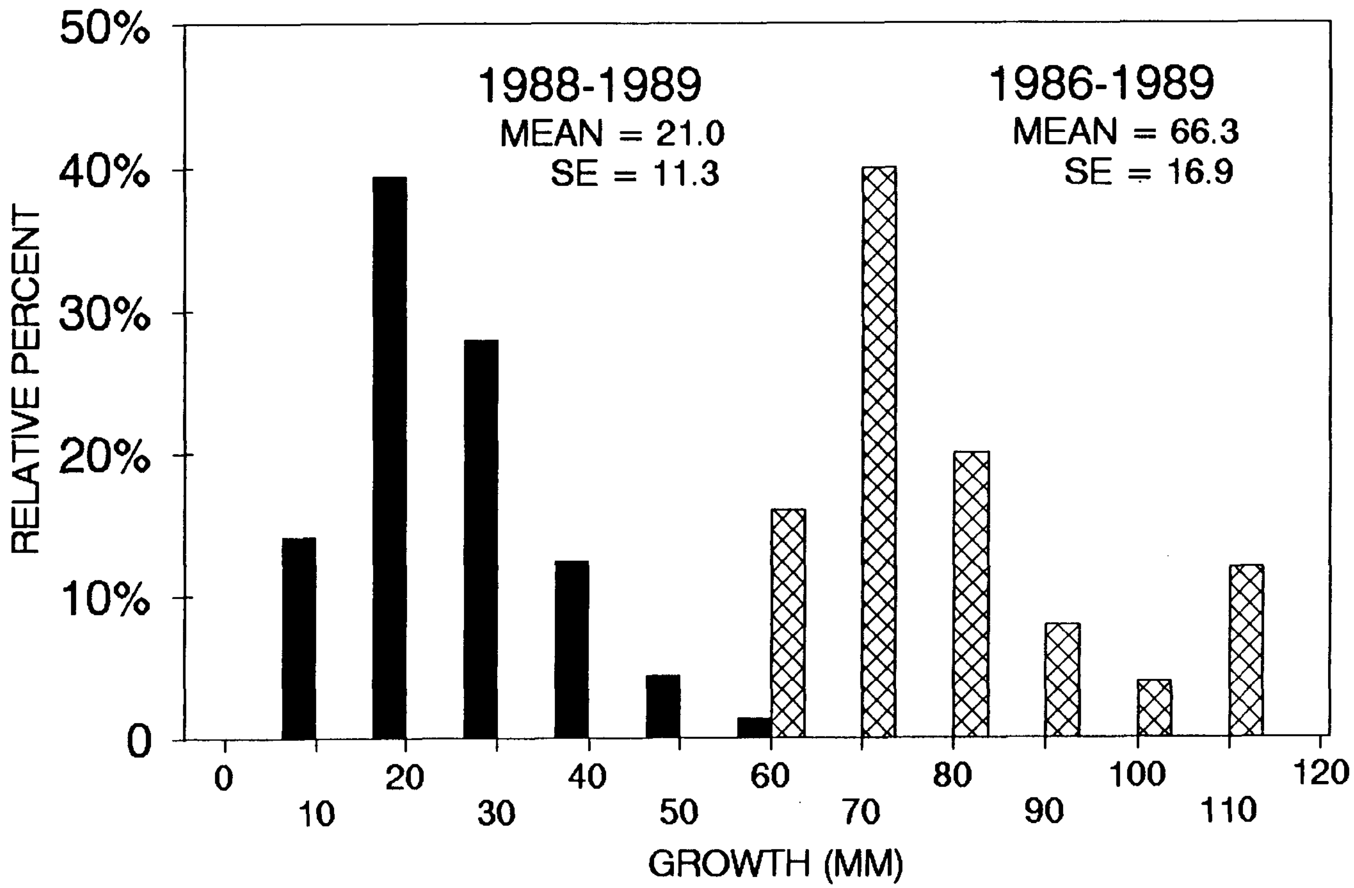


Figure 8. Observed growth of Arctic grayling sampled at the Poplar Grove weir from 1986-1989.

Table 18. Comparison of ages of Arctic grayling from the Gulkana River drainage by scales and otoliths, 1989.

SAMPLE NUMBER	SAMPLE DATE	LENGTH (mm)	SCALE AGE 1	2	3	MEAN	OTOLITH AGE 1	2	3	MEAN	DIFFERENCE
1	05/12/89	143	1	1	1	1.0	1	1	1	1.0	0.0
2	"	141	1	1	1	1.0	1	1	1	1.0	0.0
3	"	115	1	1	1	1.0	1	1	1	1.0	0.0
4	"	253	5	5	4	4.7	3	3	3	3.0	-1.7
5	"	187	3	3	3	3.0	3	3	3	3.0	0.0
6	"	119	1	1	1	1.0	1	1	1	1.0	0.0
7	"	168	3	3	2	2.7	2	2	2	2.0	-0.7
8	"	176	3	3	3	3.0	3	3	3	3.0	0.0
9	05/17/89	224	4	4	3	3.7	3	3	3	3.0	-0.7
10	"	235	4	4	4	4.0	3	4	3	3.3	-0.7
11	"	244	4	4	3	3.7	3	3	3	3.0	-0.7
12	"	233	5	5	3	4.3	3	3	5	3.7	-0.7
13	"	247	3	3	3	3.0	5	3	3	3.7	0.7
14	05/18/89	256	5	5	4	4.7	3	4	3	3.3	-1.3
15	"	221	2	2	2	2.0	3	3	3	3.0	1.0
16	"	223	3	3	3	3.0	3	3	3	3.0	0.0
17	"	208	3	3	3	3.0	5	4	5	4.7	1.7
18	06/09/89	325	7	6	6	6.3	7	5	7	6.3	0.0
19	06/21/89	345	6	6	6	6.0	7	6	7	6.7	0.7
20	"	255	3	3	3	3.0	4	4	4	4.0	1.0
21	06/22/89	329	6	6	6	6.0	6	4	6	5.3	-0.7
22	06/23/89	373	5	5	6	5.3	6	7	6	6.3	1.0
23	"	321	5	3	5	4.3	6	6	6	6.0	1.7
24	06/24/89	303	4	4	3	3.7	4	4	4	4.0	0.3
25	"	304	5	5	6	5.3	5	5	5	5.0	-0.3
26	"	76	1	1	1	1.0	1	1	1	1.0	0.0
27	06/25/89	308	6	6	6	6.0	7	6	7	6.7	0.7
28	"	285	6	6	5	5.7	6	6	6	6.0	0.3
29	06/26/89	260	4	4	4	4.0	5	5	5	5.0	1.0
30	"	332	6	6	5	5.7	6	5	6	5.7	0.0
31	06/27/89	300	5	5	5	5.0	5	5	5	5.0	0.0
32	"	322	5	5	5	5.0	6	6	6	6.0	1.0
33	"	322	5	5	5	5.0	5	5	5	5.0	0.0
34	07/27/89	279	4	4	4	4.0	4	4	4	4.0	0.0
35	"	215	R	R	R	0.0	3	3	3	3.0	3.0
36		135	1	1	1	1.0	1	1	1	1.0	0.0
37	09/29/89	355	R	R	R	0.0	4	4	4	4.0	4.0
38		238	2	2	3	2.3	2	2	2	2.0	-0.3
39		125	1	1	1	1.0	1	1	1	1.0	0.0
40	09/01/87	189	3	3	3	3.0	2	2	2	2.0	-1.0

-Continued-

Table 18. (Page 2 of 2).

SAMPLE NUMBER	SAMPLE DATE	LENGTH (mm)	SCALE AGE				OTOLITH AGE				DIFFERENCE
			1	2	3	MEAN	1	2	3	MEAN	
41	09/18/87	255	4	4	4	4.0	3	3	3	3.0	-1.0
42	09/17/87	275	7	7	6	6.7	6	6	6	6.0	-0.7
43	08/29/87	225	2	2	2	2.0	2	2	2	2.0	0.0
44	09/18/87	345	5	5	5	5.0	4	4	3	3.7	-1.3
45	"	291	5	5	3	4.3	4	4	4	4.0	-0.3
46	09/19/87	253	6	6	5	5.7	5	5	5	5.0	-0.7
47	07/16/87	230	4	4	4	4.0	4	4	4	4.0	0.0
48	08/28/87	325	4	4	3	3.7	3	3	3	3.0	-0.7
49	08/23/87	281	4	4	4	4.0	5	5	4	4.7	0.7
50	09/18/87	295	6	6	6	6.0	4	3	4	3.7	-2.3
51	07/26/87	240	3	3	3	3.0	3	3	4	3.3	0.3
52	09/03/87	266	5	5	5	5.0	I	I	I		

Figure 9. Comparisons of ages of grayling (n = 50) as determined from aging scales and otoliths.

Age Composition of the Sport Harvest

One hundred and sixty-two heads were collected from Arctic grayling harvested by sport anglers from the Gulkana River during 1989. Nearly 70% of these grayling were either age 4, 5, or 6 (Table 19).

Abundance Estimates

An estimate of grayling abundance in the mainstem Gulkana River was generated using the recaptures of Poplar Grove tags in the Sourdough and Float reaches during July and August. The estimates, which are significantly different from each other, were 89,725 and 282,283 for the Sourdough and Float recaptures respectively, and 205,621 for the combined data (Table 20). If we could assume that grayling remain stationary during July and August and that Poplar Grove Creek grayling distribute evenly only throughout the mainstem river, this would then represent the population for the mainstem of the Gulkana River. However, based on the observed significant differences in the tag-to-untagged ratios of grayling tagged in Poplar Grove Creek in these reaches during July and August, it does not appear that these assumptions were met.

The observed significant differences in tag-to-untagged ratios may be due to the length segregation that is apparent in the mainstem during July and August. As was shown earlier, smaller grayling tend to remain in the Sourdough reach while larger grayling tend to migrate into the Float reach during July through August. The adult grayling observed in the Sourdough reach were significantly smaller than those sampled from the Float reach during July and August (Figure 10, Table 7). The tagged-to-untagged ratios of grayling tagged in Poplar Grove Creek were stratified by length to test the hypothesis that tagged-to-untagged ratios were not different between reaches within length strata and within reaches between length strata (Table 21). There was a significant difference between length strata for the Float ($P < 0.05$) and Sourdough ($P < 0.10$) reaches and between reaches within length strata ($P < 0.05$). We concluded based on this that stratifying by length will not improve the estimates. A higher proportion of the grayling tagged in Poplar Grove Creek migrate to and remain in the Sourdough reach over both length strata than in the Float reach (Table 21). This supports our earlier conclusion that grayling tagged in Popular Grove Creek do not randomly mix in the mainstem.

A second population estimate can be made using the stratified Petersen estimator (Table 22) with the Sourdough and Float reaches representing two strata, with releases in June and recoveries in July/August. This allows for the migrational movements between the two strata, i.e. within the mainstem area including the Sourdough and Float reaches. This estimate gave a total of nearly 67,599 adult Arctic grayling in the two strata. The Float reach had an estimated population of 56,848 adult Arctic grayling whereas the Sourdough reach had an estimated population of 10,751 adult Arctic grayling. However, the stratified Petersen estimator assumes a closed population with no emigration from or immigration into the strata. The lack of information available on migration patterns into the tributaries or to areas below the

Table 19. Age composition statistics for Arctic grayling harvested in the sport fishery on the Gulkana River, 1989.

Parameter	Age Class 1	2	3	4	5	6	7	8	All
Percent	0	9.9	19.1	29.0	21.6	13.6	4.9	1.9	100.0
Standard Error	---	0.1	0.1	0.1	0.1	0.1	0.0	0.0	---
Sample Size	0	16	31	47	35	22	8	3	162

Table 20. Estimates of the abundance of Arctic grayling in the Gulkana River drainage during 1989.

Area		Abundance	Standard Error	Relative Precision[a]
DRAINAGE TOTAL (Poplar Grove Creek releases)				
Sourdough Recoveries	Petersen	89,725	25,276	55.2%
Float Recoveries	Petersen	282,283	72,236	50.2%
All Recoveries	Petersen	205,626	40,597	38.7%
FLOAT REACH	Stratified-Petersen	56,848	15,049	51.9%
SOURDOUGH REACH	Stratified-Petersen	10,751	3,406	62.1%
BOTH REACHES	Stratified-Petersen	67,599	13,974	40.5%

[a] $\alpha = 0.05$.

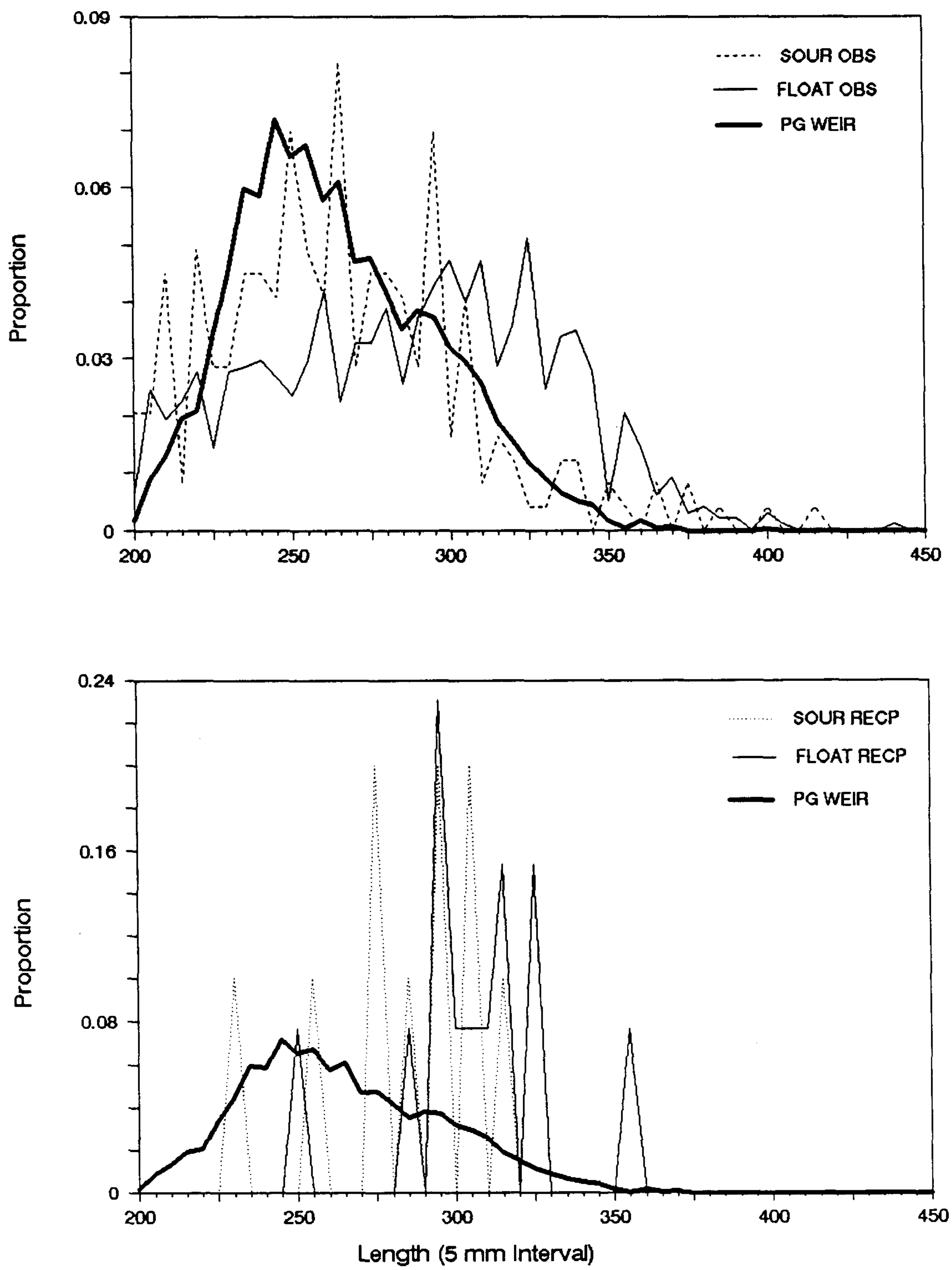


Figure 10. Length distributions comparing the adult grayling (A) tagged at the Poplar Grove weir and observed in the Sourdough and Float reaches and (B) tagged at the Poplar Grove weir and recaptured in the Float and Sourdough reaches during 1989.

Table 21. Marked-to-unmarked ratios, by length stratum, of adult Arctic grayling marked at the weir on Poplar Grove during 1989 and recaptured in the Float and Sourdough reaches during July and August, 1989.

Reach	Stratum		< 290 mm	≥ 290 mm	χ^2
Sourdough	Tagged		5	5	
	Untagged		179	54	3.8[a]
	Percent Tagged		2.8	9.2	
Float	Tagged		2	11	
	Untagged		487	474	6.4[b]
	Percent Tagged		0.4	2.3	
		χ^2	6.9[b]	7.1[b]	

[a] Significant at α = 0.10.
[b] Significant at α = 0.05.

Table 22. Summary of tag releases and recoveries, by stratum, for Arctic grayling in the Gulkana River, 1989.

Release Reach	Recovery Reach		Number Recovered	Number Not Recovered	Number Released	Percent Recovered
	Float	Sourdough				
Float	17	3	20	1,104	1,124	1.8
Sourdough	4	15	19	873	892	2.1
Tagged	21	18	39	1,977	2,016	
Untagged	955	225	1,180			
Examined	976	243	1,219			
% Tagged	2.2	7.4				

Sourdough reach is a problem as the major assumption of a closed population cannot be tested.

All these abundance estimates include all adult grayling sampled, without adjusting for growth recruitment. If there is growth, which would seem reasonable as tags were placed in May and June and recoveries were made in July and August, then there will be an overestimate of the abundance. However, due to small sample sizes, it was not possible to assess the amount of growth recruitment that had occurred.

DISCUSSION

Most of the results for the 1989 studies were similar to the results reported for earlier studies of Arctic grayling in the Gulkana River drainage (Roth and Alexandersdottir in preparation). Both studies showed that Arctic grayling in the Gulkana River drainage undergo intensive migrations after spawning. The Arctic grayling which spawned in Poplar Grove and Sourdough Creeks later redistributed throughout the Float and Sourdough reaches of the Gulkana River. However, unlike the grayling which were tagged in Sourdough Creek during 1987 and which later randomly redistributed in the mainstem, the grayling which were tagged in Poplar Grove Creek during 1989 did not randomly redistribute after spawning. A higher proportion of the Poplar Grove grayling migrated to and remained in the Sourdough reach than migrated to the Float reach (Table 21). Whether this difference is the result of differential migrational habits of the two spawning stocks or just annual variation in migrational habits is unknown at present. It may not be reasonable to expect Arctic grayling to randomly distribute throughout the Gulkana River drainage after spawning given this propensity to distribute non-randomly by age and length.

A sizable fraction of the Arctic grayling that spawned in Poplar Grove Creek during 1989 were repeat spawners. Just over 30% of the Arctic grayling captured at the weir in Poplar Grove during 1989 had been observed at the weir in 1988.

The patterns of spatial distribution by size and age observed for grayling in the mainstem during the summer of 1989 were also similar to those reported in Roth and Alexandersdottir (in preparation). In all years, larger and older grayling tended to be found in upstream areas. Consistent differences in mean length, age composition, and size of recaptures were observed between the upstream and downstream study reaches within the mainstem river in both studies. These results are similar to patterns of spatial distribution reported for grayling by Tack (1980) and Ridder (1989). A lack of recoveries of age 0 grayling in the mainstem river indicates that this age class spends its first summer in the spawning tributaries. This is supported in the finding of small (mean length = 66 mm) Arctic grayling in Poplar Grove Creek during September (Table 7).

As was the case in previous years, the ratios of tag-to-untagged grayling decreased in all reaches over the summer, with highest availability of tagged fish occurring in June. This dilution is probably due to several factors including continued migration of the tagged groups out of the study area, the recruitment of grayling to the gear that were too small to tag in the spring and early summer, and the movement of untagged grayling from the Middle and West Forks into the mainstem study reaches. In all likelihood, these factors act in combination.

The fact that fish tagged in Poplar Grove did not randomly mix in the mainstem results in biased Petersen estimates of abundance and the extent of this bias is unknown. Given this, the mainstem Petersen estimates of abundance are currently of no use in managing Arctic grayling in the Gulkana River.

The stratified Petersen estimator also yielded higher estimated abundances for the Sourdough and Float reaches during 1989 than during 1987 (Table 23). The reasons for this are unclear. It is possible that growth recruitment influenced the 1989 estimate more than the 1987 estimate as tags were recovered for an extra month during 1989.

The Darroch estimator potentially provided sufficient estimates of abundance; however, we believe that growth recruitment occurred. This can be tested by examining recapture rates among lengths of grayling and potentially stratifying the Darroch estimate by length. We did not perform these tests at this time and prefer to gather an additional year's data to see if this approach is viable.

The questions still remain in 1989, as in 1987, as to the boundaries of the population for which the abundance is being estimated. If Arctic grayling distribute evenly throughout the drainage after exiting their spawning streams (such as Poplar Grove or Sourdough Creeks), a population estimate based on weir tagging would be a drainage-wide abundance. If there is uneven distribution, then the estimate from weir releases cannot be geographically bounded nor will it be an unbiased estimate. Other reaches of the Gulkana River need to be sampled in July and August including the tributaries in order to determine if these migration patterns hold true in areas other than the Sourdough and Float reaches.

RECOMMENDATIONS

It is recommended that mark-recapture studies be continued on the Gulkana River drainage, including the operation of weirs at Poplar Grove Creek, and if possible at Sourdough Creek. The observed differences of movement and stasis demonstrated for the grayling tagged in the Sourdough and Poplar Grove Creek weirs will need to be tested to determine if the differences are the result of differential migrational habits of the two spawning stocks or just annual variation in migrational habits. Also, sampling needs to be conducted in the West Fork, the Middle Fork, and the reach downstream from Sourdough to determine if tagged-to-untagged ratios of weir tagged fish are similar between these reaches and previously studied reaches.

Surveys and tagging efforts should be expanded to other areas of the Gulkana River drainage to determine if discrete stocks are present and, through tag

Table 23. Comparison of abundance estimates generated for Arctic grayling in the Gulkana River drainage.

Area	1989 Abundance	1989 Relative Precision[b]	1987[a] Abundance	1987[a] Relative Precision[b]
DRAINAGE TOTAL				
Sourdough Recoveries	89,725	55.2%	162,000	64.1%
Float Recoveries	282,283	50.2%	148,000	39.7%
All Recoveries	205,626	38.7%	140,000	36.4%
FLOAT REACH	56,848	51.9%	22,234	39.0%
SOURDOUGH REACH	10,751	62.1%	9,854	36.9%
BOTH REACHES	67,599	40.5%	32,088	27.0%

[a] From Roth and Alexandersdottir (in preparation).
[b] $\alpha = 0.05$.

recoveries, determine if these areas contribute to the mainstem river sport fishery. These areas should include Paxson Lake and the reach of the Gulkana River upstream of the lake, the Middle Fork and West Fork and their major tributaries and associated lake systems, and the reach of river downstream from Sourdough. Efforts should also be made to document other spawning tributaries and the extent of mainstem river spawning. A sampling design which further delineates the Gulkana River into more definitive sublocations will allow the collection of more specific information on intrastream migration patterns.

It is recommended that future tagging efforts include the analysis of tag loss. Although tag loss was apparent with some recaptured fish, the extent of tag loss could not be determined due to the multiple secondary marks put out in the Gulkana River during previous studies.

The collection of otoliths from the sport fishery should be continued. This information is necessary for the construction of a database necessary for the estimation of mortality and recruitment.

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APPENDIX A

Appendix A1. Summary of tag numbers deployed during 1989 in the Gulkana River for marking Arctic grayling.

Reach	Dates	Tag Numbers Deployed
Poplar Grove Weir	5/05-5/18	11277-14014
Sourdough Reach	6/06-6/13	14015-14788
	7/13-7/18	15778-15790
	8/21-8/28	50702-50899
	9/26-10/04	51190-52535
	10/11-10/18	52536-52637
Float Reach	6/21-6/29	14789-15777
	7/27-8/05	15791-16000, 50026-50701
	9/12-9/19	50900-51168
	10/13	52638-52642
Lower River Reach	10/18	52643-52702

Appendix A2. History of Arctic grayling recaptured during the 1989 field season

Tagging History			1989 Recapture History				
Year	Area	# Tagged	Poplar Grove	Sourdough	Float	Lower River	All
1986	Float	1,069	0	1	5	0	6
	Sourdough	971	0	0	0	0	0
	Poplar Grove Ck.	3,095	34	2	1	0	37
1987	Paxson Lake Out.	93	0	0	1	0	1
	Float	2,656	6	11	24	0	41
	Sourdough	4,178	25	55	29	0	109
	Lower River	155	6	0	1	0	7
	Sourdough Ck.	1,591	1	13	26	0	40
1988	Mainstem Misc.	1,145	39	56	13	0	108
	Sourdough Ck.	81	0	2	1	0	3
	Poplar Grove Ck.	4,906	1,272	43	26	0	1,341
1989	Poplar Grove Ck.	4,044	---	61	28	0	89
	Sourdough	2,780	---	136	36	0	172
	Float	2,414	---	28	62	0	90
	Lower River	60	---	---	---	0	0
All[a]		29,238	1,383	408	253	0	2,044

[a] Totals may exceed the observed number of recaptures due to multiple recaptures of tagged Arctic grayling over the past years.